Weatherwise

Great Snows of the Great Lakes

Hilo—Hawaii's First Hurricane of Record

In the Eye of a Hurricane

The Great Smoke Pall — September 24-30, 1950

The Florida Hurricane

Vol. 3, No. 6, December, 1950

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE" — BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

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In the Eye of a Hurricane

ON OCTOBER 16, 1950, when it appeared that the tropical revolving storm located south of Cuba would be in the Atlantic off the north coast of Cuba the following morning, arrangements were made with Capt. Paul Drouilhet, of the Naval Hurricane Weather Central, for me to go with the reconnaissance crew into the storm.

On October 17, 1950, I reported to the Naval Air Station, where the briefing of the crew was observed. In the briefing, the estimated position of the storm and the probable flight conditions were given. Take-off was at 0744 EST, and with an altitude of 700 feet a heading of 150 degrees was taken. The storm was estimated to be about 150 miles SSE of Miami.

At 0850 EST, the surface wind was estimated 70 degrees at 40 knots with a pronounced swell and many whitecaps. Although we had clouds with scattered squalls, the storm area ahead appeared very black. At 0820 "green water" was observed, indicating a velocity of 50 knots, and at 0845 the sea began to show streaks with a velocity of 70 knots. The squalls had increased by this time in frequency and intensity, but contact with the surface was possible except in the very heaviest precipitation.

The aircraft radar showed the squalls very clearly, and a circular area began to show slightly to the right of the heading. A change of heading was made to 180 degrees, toward the area which began to show up clearer as the eye of the storm. At 0849 the sea surface was white, with extremely long streaks and an estimated wind of 75 knots at 90 degrees. We broke through the wall of the eye at 0854. There the surface wind dropped very rapidly to 10-15 knots, with a variable direction and a confused sea surface. The winds through the wall were estimated to be 90 knots at 90 degrees, with gusts to 100 knots. The sea was very white with extremely long streaks. Rainfall was heavy, but only moderate turbulence was observed.

A considerable amount of cloudiness existed in the 20-mile diameter eye; however, 1/10 to 2/10 blue sky and the sun were visible, as were a large number of birds. About 15 minutes were spent in the central area while the navigator and the aerologist caught up on their work. The radar operator kept the captain advised as to the location of the aircraft in order to keep within the eye, and at 0915 advised that breaks in the wall were observed to the south. It was then decided to leave the eye on a 150-degree heading. When this course was taken the captain advised everybody, "Hold your hats, here we go." This 150-degree heading was maintained until the surface wind indicated 55-60 knots. Then the aircraft was turned to the left, and the wind was kept directly on the tail until we reached the north side of the storm, when a direct heading for Miami was taken. The maximum wind encountered on leaving the storm was 210 degrees, 80 knots. The aircraft was "on the deck" at the Naval Air Station at 1025, after an elapsed flight of two hours and 41 minutes.

WILMER L. THOMPSON
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Cover: Digging out from one of the paralyzing blizzards that struck Watertown, New York, from late February through the first two weeks of March, 1947. Photo by Watertown **Daily Times.**

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No freight can move over a snow-covered track such as this one in the South Buffalo railroad yards, after one of Buffalo's typical snowbursts. New York Central Railroad photograph.

Great Snows of the Great Lakes

B. L. WIGGIN, U. S. WEATHER BUREAU, BUFFALO, NEW YORK

IN SOME CITIES you board a snow train to get to favorite skiing and tobogganing slopes. But if you are on the right side of the Great Lakes, the snow comes to you. Any time after the autumnal equinox, when cold air masses start sliding southward from the polar regions, convective clouds mushroom up to icy heights above the warm, energy-giving waters of the lakes to drop their precipitation on the lee shores with the whimsey of April showers—and sometimes with the numbing punch of the full-blown blizzard.

As the weekend of October 18-19, 1930, approached, many Buffalonians, enchanted by the Indian summer haze, dreamed of trips to the countryside. Apple, plum, and pear trees were heavy with fruit; bees hummed among fall flowers, dairy herds grazed in the still-green pastures. To take advantage of nature's kindliness, a troop of girl scouts left on Friday afternoon for a weekend camp at Farnum, 25 miles southwest of Buffalo.

Saturday brought a change of wind and a disappointing turn to cooler temperatures. There were even some foreshadowing snow flurries in Buffalo before daybreak. Many who had planned outings started anyway, as the sun peeked through the clinkerlike clouds and took a little edge off the sharp air pouring in from the west. But the autumnal scene was soon changed into a winter wasteland by one of Lake Erie's typical pranks.

Over a thousand cars and many times more people, including the girl scouts, were marooned in up to four feet of snow that gushed out of the black overcast that October Saturday and Sunday. It was a wet snow, big feathery flakes in a smothering snowburst. Twenty-five persons were forced to flee the Angola Hotel, when bulging walls warned that the roof could no longer sustain the crushing burden of wet snow. Hundreds of small buildings along the lake shore collapsed under the weight of moisture that nature had miraculously transformed from warm lake water to cold snowdrift.

At the same time, at the eastern end of Lake Ontario, in the area from Watertown to De Kalb Junction, snowfall ranged from 21 to 36 inches. At Gouverneur, a little

Whither points a sign when road and field in central Erie County lie under the deep mantle of one of western New York's snowfalls? Photo, N. Y. State Dept. of Public Works.

farther inland, it was measured at 47 inches. Nine inches fell in Buffalo's south side, but only a few flurries drifted down north of Walden Avenue, running east-west through the center of the city. This was typical of the behavior of the lee shore snowstorms of the lower Great Lakes.

Later in the season even greater storms have come roaring in from the lake. In January, 1940, a snowburst buried the eastern end of Lake Ontario's shoreline and countryside in depths up to eight feet on the level, and this was blown later into drifts 20 feet high. Another memorable storm hit the Buffalo area during December 8-10, 1937, when a series of heavy snow showers laid down three feet of snow on the level in north Buffalo, and over four feet in the suburbs of Kenmore and Tonawanda. All of the rescue operations usually associated with mountain country were employed to bring food and relief to marooned persons.

In 1945, a Lake Erie storm on December 14-18 buried the vital marshalling yards of south Buffalo under a blanket of over three feet. The airport measured 36.6 inches and there were estimated falls of 70 inches just four to six miles to the south. The governor of New York declared a state of emergency, and an embargo on further rail shipments of freight was clamped on this transportation hub.

During the past 50 years, however, there have actually been only 148 snowstorms that dropped five inches or more snow in Buffalo streets, an average of about three such storms a year. Three years did not have any heavy snowfalls, and there were only nine snow seasons that had as many as five or six — quite narrow deviations. But these city statistics would not hold for all of rural western New York, where the frequency of heavy snows is more nearly two or three times as great in two fairly well-defined snowbelts, one for each lake.

The Lake Erie snowbelt begins just south of Buffalo and extends along the south shore to the Chagrin Hills, near Cleveland, Ohio. In general, the heaviest and most frequent snows begin near Buffalo in November. As the season advances, the snowbelt moves southwestward, until by late December or January the heaviest local snows occur near the New York-Pennsylvania border. The icecover of Lake Erie plays its part and keeps pace in this advance up the lake.

Lake Ontario's snowbelt is larger, taking in about all the American side of the lake. Beginning to the west of Rochester it extends eastward around the end of the lake, tapering off sharply as the St. Lawrence River is reached. More snow falls in the zone between Syracuse and Watertown eastward to the Adirondack Mountains than in any other area east of the Rockies. The average winter accumulation is well over 150 inches on the highlands back from the lake.

Typical lake snows are believed to account for at least 40 per cent and possibly as much as 55 per cent of all heavy snows recorded at Buffalo. Over 70 per cent of November's snowstorms originate from the relatively warm waters of Lake Erie. For all later months (December-March) approximately half the snowstorms are of cyclonic origin. The Lake Ontario snowbelt differs, with an appreciably larger percentage of snow that can be traced to the lake. Lake Ontario seldom has much of an icecover; hence its lake snows persist into the late winter months.

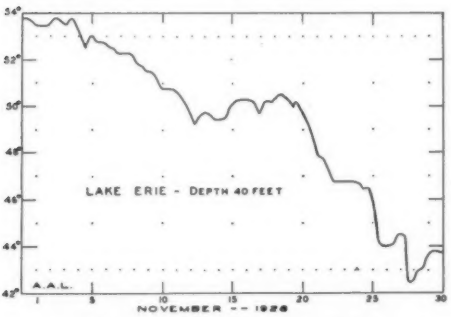
The blizzards of February-March, 1947, were good examples (see front cover).

Let us consider the basic physical principles involved. We know that instability arising from the passage of polar air over the relatively warm lake surfaces is the prime cause of these snowstorms. Based on cumulative experience, the Weather Bureau staff at Buffalo tentatively holds that the following factors operate to produce heavy lake snowstorms:

1. A strong flow of cold polar air with a lee shore lapse rate adiabatic or greater to over 5,000 feet.
2. Cyclonic curvature to the flow pattern.
3. A large temperature differential between the air and water to build up the thickness of unstable air, and to cause a rapid flux of moisture from the lake surface to the air.
4. A long fetch over water.
5. A shear to produce longitudinal convective cells.

There is great need for extensive observational data. Records of Lake Erie surface water temperatures show that it cools each autumn in an irregular manner, suggesting that a one-point temperature reading may not be representative of all surface water conditions. Such data are required to begin a study of the complete weather machine that sits so complacently on our doorstep one day and buries us in snow the next.

The following general observations have been noted over quite a long period of time:



The cooling of the waters of Lake Erie during November, 1928, 40 feet below the lake surface. Fifteen feet below the surface the cooling was along nearly the same curve. From records kept by W. Q. Williams, City of Cleveland engineer, from recording thermometers four miles offshore at the crib intake tunnels for Cleveland's water supply. Ice jams during the winter of 1928-29 sheared off the installation.

The regions on the lee shores of the lower Great Lakes that are subject to sudden snowbursts.

1. Where the flow of polar air is limited in depth, all other factors being favorable, a great amount of cloud is produced but only a few snow flurries.
2. If the shear aloft is marked, as for fast-moving polar maritime air from the west overrunning polar continental air, only a few flurries are produced.
3. A deep outbreak of cold polar continental air with anticyclonic curvature may produce numerous flurries, some of them briefly blinding in intensity, but usually no great amount of snowfall.
4. It appears that polar continental air of great depth, with 20° F. or more temperature contrast with the lake surface and a straight or cyclonic flow across the lakes, will produce cloudbursts of snow at one or more places on the lee shores.
5. If the shear is favorable, a longitudinal cell is believed to form. It will perpetuate itself for hours, literally dumping the snow into a narrow strip, the width being proportional to the depth of cold air, about three to one.
6. The strip will usually vary between three and five miles in width and extend inland from the lake about 15 miles.
7. Such cells persist for several hours, at times with apparent undulations along the long axis of possibly 10 degrees amplitude.
8. Occasionally a longitudinal cell will break down, then form again with a different orientation.

Lakes Michigan and Superior have their snowbelts, too. The Keweenaw Peninsula of extreme northwestern Michigan averages better than 130 inches of snow a year. A snow

pocket between Lake Superior and Lake Huron in northern Lower Michigan accumulates more than 90 inches of snow on the average, with wide departures from year to year. Occasional storms drop three or four feet at a time, as in the storm of January 15-20, 1950, with a total of 46.1 inches at Calumet, Michigan.

Chicago, at the lower tip of Lake Michigan, experienced one of its worst snowstorms, March 24-28, 1930, with 19.1 inches in 44 hours. This was a cyclonic storm augmented by lake effects. A low pressure center over Indiana remained stationary for 24 hours while deepening, and then it moved slowly northeastward, keeping Chicago in a steady flow of unstable air with a fetch down the entire length of Lake Michigan. All traffic was paralyzed, schools closed, and a milk shortage developed. Two weeks later Chicago's temperature rose to 90°.

Lake-borne snows play an important part in the area's economics. Snow removal is a several million dollar item in Erie County, the 14th largest county in the United States in number of people. Possibly the greatest aggregation of snow removal equipment in the world is concentrated in western New York, operating under the New York State department of public works and the county, city, and village governments. Residents of this area take great pride in the almost superhuman achievements of their snow fighters.

There is a plus side to the economic balance sheet, however. The Niagara Mohawk Power Corporation, exercising a little patience, gathers in millions of kilowatt hours of electric energy almost every spring as the snow melts to run back into the lakes, turning on the way the wheels of many strategically placed hydroelectric generators.

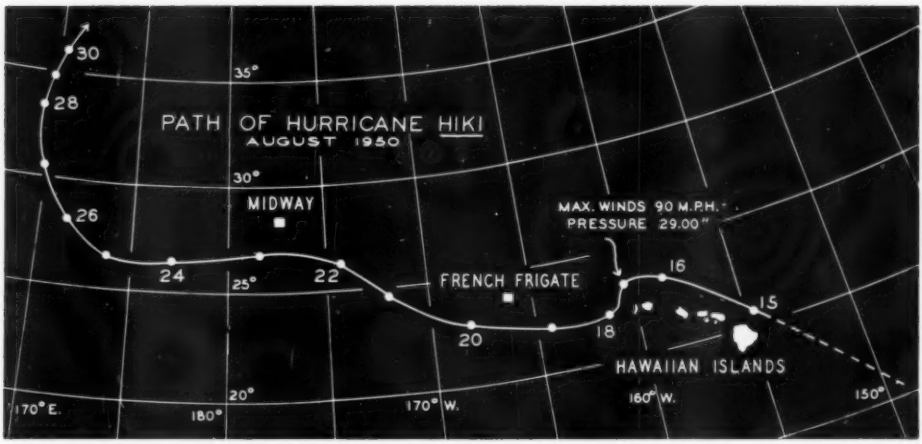
If you are a stranger driving through western New York or western Michigan in the late fall or winter months, remember that the weather here often "clears up stormy." If the temperature falls as the sky fills with huge towering clouds, and snow begins to sift down, watch out. When the brave west wind plaits the newly fallen snow into careless braids, dragging them willy-nilly across the road and into the fields, you had better skip the poetry inherent in the scene. Instead tune in for the current weather forecast. And if heavy snow squalls are featured, then consider choosing your shelter for the night while you can.

SOME HEAVY SNOWSTORMS
NEAR THE GREAT LAKES

Buffalo, N. Y.	1936,	Mar. 17-18	19.5″
	1945,	Jan. 1-4	25.1
	1945,	Dec. 14-16	36.6
	1949,	Nov. 15-17	19.2
Erie, Pa.	1901,	Apr. 20	15.4″
	1936,	Mar. 17-18	16.2
Oswego, N. Y.	1947,	Mar. 1-5	29.6″
Rochester, N. Y.	1879,	Jan. 3-5	25.5″
	1900,	Feb. 28-Mar. 2	43.5
	1944,	Dec. 11-13	22.0
Syracuse, N. Y.	1925,	Jan. 29-30	27.5″
	1944,	Nov. 29-Dec. 2	31.4
	1947,	Mar. 1-5	23.3
Watertown, N. Y.	1900,	Nov. 14-15	49.0″
	1947,	Mar. 2-5	39.9

ED. NOTE: Figures for the great storm of late November, 1950, are not yet available as we go to press.

Snow disposal is a serious problem along Fuhrmann Boulevard (New York Route 5) on Buffalo's industrial waterfront, which plays host to most of Lake Erie's storms. The lake is within a stone's throw of this scene. The picture was taken in the month of February, 1945.



The path of HIKI, a hurricane in the Pacific in August, 1950.

Hiki—Hawaii's First Hurricane of Record

IN August, 1950, the Hawaiian Islands came under the influence of a tropical cyclone of full hurricane force. This is the first instance in 45 years of meteorological records in this area that a storm of such intensity has approached so close to the islands. Inasmuch as this was the first Hawaiian hurricane, it was designated as ABLE, or in the Hawaiian language, HIKI. Thus, it became widely known as Hawaiian hurricane HIKI.

It was first detected on the charts at the Honolulu Airport during the night of August 13th. It moved into the Hawaiian area from the vast region southeast of the islands where reports are rarely available and about which little is known meteorologically. Such data as has been available in previous years has indicated that the intertropical convergence zone between 120° and 168° west longitude normally does not advance far poleward into the summer hemisphere. Hence, the trade winds of the Northern and Southern hemispheres rarely converge at large angles, the shift frequently being only from east-northeast to east-southeast.

Scattered ship reports from the area this summer had shown the intertropical convergence zone to be farther north than usual on several occasions, with a westerly flow as far north as the 10th parallel, a condition favorable for the development of tropical cyclones. The research ship *Horizon* encountered these westerlies near the 145th meridian, south of the region where HIKI probably formed, at approximately the time of the storm's inception.

HIKI arrived east of Hilo an immature storm of very small diameter. Airplane reconnaissance on August 14th estimated surface winds of 45-50 knots near the center. During the next 24 hours, the storm intensified, reaching full hurricane force; however, it remained of small diameter, and gale force winds extended outward less than 150 miles. The northwest movement of the hurricane became blocked temporarily on August 17th as a high pressure ridge west of the Hawaiian Islands intensified. During the next 24 hours, the hurricane was forced slowly southward, seemingly poised between lower troposphere currents which would have carried it farther westward and higher-level westerlies which tended to carry it northeastward. At this stage, an airplane reconnaissance reported winds up to 90 miles per hour just south of the storm center, and it became necessary to alert the populations of Kauai and Oahu against possible loop movement of the hurricane, which would have carried it east and northeastward through the Kauai channel.

Fortunately, the blocking action to the west eased and HIKI resumed its westward movement, passing south of French Frigate Shoal and Midway Island before it began its re-

curvature near 170° in the eastern hemisphere.

Distinguishing features of HIKI's recurvature were that the movement of the hurricane was not accelerated and that, as colder air circulated into its lower vortex from the north on the 29th and 30th, it came virtually to a standstill and filled rapidly. Ships reporting near the storm center at that time indicated that maximum winds diminished there from more than 85 miles per hour to less than gale force.

The eye of the storm was entered by two reconnaissance planes and several ships. It was described as being 20-25 miles in diameter, overcast, with lowest pressure 29.00 inches.

Since all of Hawaii remained in the southern or less dangerous semicircle of the hurricane, HIKI caused little wind damage. The highest sustained winds reported were at Kilauea, Kauai, 68 miles per hour; Wiihau, 50 miles per hour; and Lanai Airport, 48 miles per hour. The roofs of several houses were blown off, and unbraced masonry walls of one house under construction were blown over. One life was lost at Kohala, Hawaii, by electrocution as a farmer contacted a live wire blown down by strong winds.

The greatest damage resulted from flooding of the Waimea River on Kauai, where more than 200 residents had to be evacuated. As a result of adequate warnings over eight hours in advance, small craft were well secured—only two sampans were lost and three others damaged. The total damage, including that to utility lines, boats, and other property, is estimated not to have exceeded two hundred thousand dollars.

R. H. SIMPSON
Official-in-Charge
USWB, Honolulu

NORTHWEST STORMS

A series of severe storms lashed the Northwest during the last days of October, 1950, and further storms occurred in November. High winds and record-breaking rains did much damage, setting marks never reached before so early in the season. General rains began on the 25th from San Francisco northward as the series of cyclones advanced southeastward from the Aleutian low.

On October 26th an unusually deep low was centered just off the Oregon-Washington coast, and the barometer at Portland, Ore., dropped to 28.91 inches, the lowest mark by far ever reached in the month of October. Pressure at the center as the storm passed inland was 28.61 inches. Southerly winds of whole gale force created dust and sand storms inland and brought heavy rains to coastal areas. San Francisco had an October record rainfall of 0.31 inch in 15 minutes and 0.64 in one hour.

Another unusually deep low moved inland over Vancouver Island, B.C., on the 27th, with barometer readings down to 28.66 inches. And this was followed by a third low on the 28th, which brought record rains to an area already well saturated. The heaviest falls were centered in southwest Oregon and northwest California. Eureka had over nine inches in five days, with the 5.79 inches registered on the 29th setting an all-time 24-hour record. At Vollmers, California, where winds funnel up the Sacramento Valley, 13.35 inches were measured.

Disastrous floods resulted along many rivers, with the Willamette River in Oregon taking headlines because it flows through a rich, heavily populated, farm area. A flash rise of 11 feet took place on October 30th at Junction City, Ore., making 2,000 persons homeless. By the 31st, the death toll from floods in Oregon had reached four persons.

On November 18th, reports of continued rainfall and heavy floods in the Fresno area and the Kings River indicated that the northern Pacific states were still being buffeted by severe storms.

AMERICAN METEOROLOGICAL SOCIETY

The 108th national meeting of the American Meteorological Society is scheduled to be held at the Florida State University in Tallahassee on December 5-7, at the invitation of Dr. Werner A. Baum. An open house is to be held at Dr. Baum's residence on Tuesday evening, December 5th, and the following evening Dr. C.-G. Rossby is to be the dinner speaker, on problems of international co-operation in meteorology.

The first meeting in 1951 will be in New York City from January 29th to February 1st. This is the annual meeting, and official headquarters will be at the Hotel New Yorker, where all technical and social events will be held with the exception of a joint session with the Institute of Aeronautical Sciences, at the Hotel Astor on January 31st.

RAINMAKERS ON TRIAL

Does ownership of land confer ownership of the air space and clouds above? The case of "John Fayerweather" against "Henry Wetmore and Rain Control, Inc." was recently argued by 42 university and college law school teams in an interschool competition sponsored by the Association of the Bar of the City of New York. A verdict in this case with unique meteorological implications is expected in December.

The Great Smoke Pall -- September 24-30, 1950

HARRY WEXLER, CHIEF, SPECIAL SCIENTIFIC SERVICES DIVISION,
U. S. WEATHER BUREAU

DURING the last 10 days of September, 1950, a smoke pall spread over portions of Canada, the eastern United States and western Europe. Although there have been many large smoke palls observed in the past, this one was unusual in the following respects: the large area affected; the high concentration of smoke which so obscured the sun that it was visible to the naked eye without discomfort; the violet or lavender color of the sun, and to a lesser extent, of the moon; and the persistence of the smoke in the Middle Atlantic states for nearly a week. A brief preliminary discussion of this remarkable phenomenon will be presented in this general article.

Origin of the Smoke

The smoke originated in northwestern Alberta and northeastern British Columbia where, accompanying unseasonably warm weather and three weeks of drought, over 100 forest fires were burning during the week of September 17th, reaching their peak from the 22nd to the 24th; after the 27th rain and snow extinguished most of them.

Area Covered by the Smoke

By piecing together reports of the smoke from Canadian synoptic reports and questionnaires sent to 384 first-order Weather Bureau stations, the affected area was determined as shown in Fig. 1. The exact boundaries are uncertain because of difficulty in distinguishing the Canadian smoke from local smoke (especially in Georgia and Alabama), but it is believed that the smoke covered the north central states, the Great Lakes region, New England, the Atlantic coastal states as far south as Florida, and inland as far west as northeastern Illinois, Kentucky, eastern Tennessee, and Alabama.

Press reports also carried accounts of the smoke being observed in northern England, France, Portugal, Denmark, and Switzerland, on September 26th and 27th, characterized by a bluish sun and moon. Letters from the meteorological services in the Netherlands, Norway, and Belgium described a blue-colored sun and moon on the 27th, and, in the case of Belgium, on the 26th also. This indicates that the area depicted in Fig. 1 could very

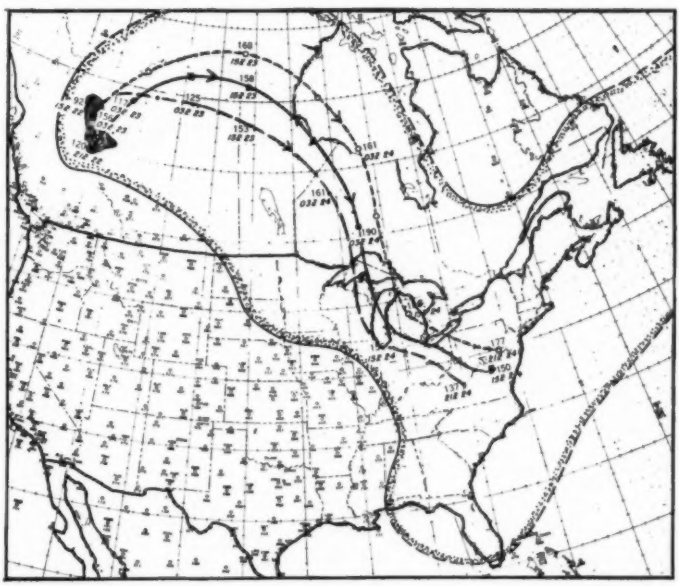


Fig. 1. The heavy shading marks the region in western Canada in which the smoke originated, and the shaded boundary the approximate area over which the smoke was observed. This area has had station numbers removed from the chart, for clearness; the boundary is dashed where it is tentative. The three curves are selected trajectories along the 312° K. isentropic surface, with date and time marks and heights at selected points given in hundreds of feet. USWB chart.

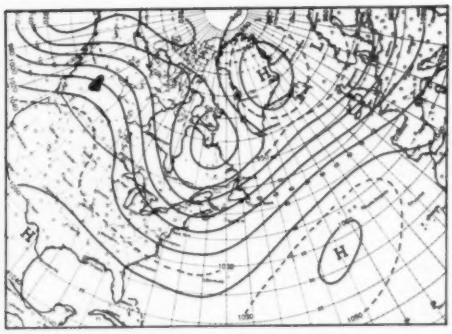


Fig. 2. The 5-day mean 700-mb chart for September 20-24, 1950.

well have been continued across the Atlantic into northwestern Europe. The extension of this area must wait upon further replies to letters of inquiry sent to Europe.

Height of the Smoke

Many reports by airline pilots of the heights of the bottom and top of the smoke were received. Although these values varied to some extent, it seems likely that the smoke observed in the eastern United States was largely confined to a layer aloft whose base was near 8,000 feet and whose top was at or above 15,000 feet. No smoke was observed at the ground in this area; in fact, the horizontal visibility was generally unlimited throughout the entire period. The soundings in the East showed a marked and persistent inversion beginning at about 5,000 feet and a weaker more sporadic inversion at approximately 15,000 feet. The smoke appeared to be confined between these two inversions, which apparently prevented spread downward, and to a lesser extent upward.

Trajectories of the Smoke

The basic flow patterns affecting the travel of the smoke are illustrated by the 5-day mean 700-mb (approximately 10,000 feet) charts for the periods, September 20-24, 23-27, and September 27-October 1 (Figs. 2, 3, and 4). The pronounced anticyclonic ridge over western North America and the cyclonic trough over the East during the first period (Fig. 2) favored movement of the smoke eastward to the Hudson Bay area and thence southeastward into the United States. This flow pattern moved eastward during the period September 23-27. In the third period, a large quasi-stationary anticyclonic eddy was located over the eastern United States. One portion of the smoke cloud became trapped in this eddy, and thus affected the Middle Atlantic states for several days, while another portion of the smoke traveled over the Atlantic with the westerlies.

However, when trajectory computations were attempted, using the individual 12-hourly 700-mb and 500-mb (18,500-foot) charts, and working backward in time from several key points where the first appearance of the smoke was definitely observed (as at Washington, D. C., 1500 GMT September 24th), it was found that the computed trajectories did not intersect the forest fire area in western Canada, but instead continued northward over the western Hudson Bay area with no sign of curving to the west, at least within the area covered by weather reports.

It was realized that there was no *a priori* reason to suspect that the smoke should move along a constant level or constant pressure surface. Rather, the airborne smoke should be expected to travel on an isentropic surface (surface of constant entropy or constant potential temperature), since the motion of air in the absence of condensation is probably fairly close to adiabatic for several days. (Non-adiabatic effects, such as radiation heating and cooling in the free atmosphere, are generally very small, less than one degree centigrade per day.) Furthermore, an isentropic surface found in the unseasonably warm air mass in which the fires were burning should slope upwards to the east where much

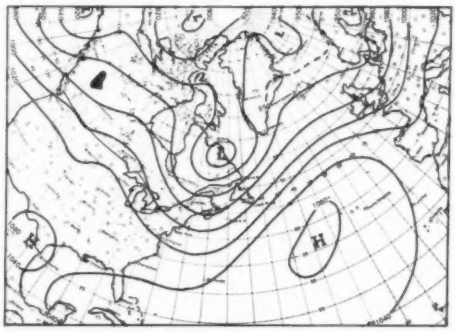


Fig. 3. The 5-day mean 700-mb chart for September 23-27, 1950.

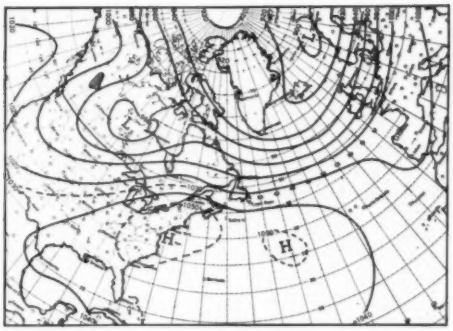


Fig. 4. The 5-day mean 700-mb chart for September 27-October 1, 1950.

colder air was located, and the streamlines on this sloping surface need not necessarily be identical with those on an isobaric or level surface. Consequently, it was decided to construct isentropic charts and to make trajectory computations on them.

The 312° K. isentropic surface was chosen because it was found at Washington at 15,000 feet, near the reported top of a smoke layer on the 24th; this particular isentropic surface intersected the smoke area near 10,000 feet, which is thought to be a reasonable height for the top portion of the smoke cloud over the fires. The isentropic trajectory, working backward from Washington, D. C., 1500 GMT September 24th, is shown in Fig. 1. It is seen that this trajectory intersected the forest fire area at 2100 GMT September 22nd, at a height of 12,000 feet, and reached its highest point at 19,000 feet in Ontario.

Two more trajectories were initiated at the fire area and carried forward in time. These are also shown on Fig. 1. It is interesting to note that one of the trajectories passed near Sault Ste. Marie, Michigan, and Buffalo, New York, at 1300 and 1800, respectively, on the 24th. These computed times compare very favorably with the observed times of first appearance of the smoke at those two cities, 1430 and 1800, respectively.

Trajectories carried on eastward from the Atlantic Coast indicated that Bermuda would not be affected, and this was later confirmed in a letter from the chief of the Bermuda meteorological service. A preliminary attempt made to extend the trajectories to western Europe on 700-mb and 500-mb surfaces indicates that the motion at these surfaces would be too slow to account for the times of first appearance of the smoke in that region. Later, isentropic trajectories will be computed to see if they result in better agreement with the times of appearance in Europe.

It is rare that such a good tracer as this smoke pall is available to check trajectory computations from meteorological data. Preliminary results indicate that trajectories computed on isentropic surfaces are more accurate than those computed on isobaric surfaces, which verifies the belief that the flow in the unsaturated free atmosphere is approximately adiabatic for periods of several days.*

Effect on Insolation and Maximum Temperatures

Solar radiation is reflected, scattered, and to some extent absorbed by smoke particles. This decreases the amount of sun and sky radiation received on a horizontal surface at the ground (insolation). The daily amounts of insolation received in Washington, D. C., during the smoky period are plotted in Fig. 5. Starting with cloudy weather values of 180 to 200 ly/day (1 ly = 1 langley = 1 gm cal/cm^2) on September 19-20, long before the smoke reached Washington, the values dropped to less than 100 ly/day on the rainy, foggy days of the 21st and 22nd. On the 23rd, following a cold front passage, the insolation increased markedly, but was still about 100 ly below the value for an average clear day (495 ly) because of a high overcast and scattered low clouds.

At 0700 EST on the 24th, only 2/10 cirrus clouds were reported, probably the last visual evidence of a second cold front which passed during the night. At 1000 EST, 10/10 "cirrostratus" and a few cumulus clouds were reported. It is likely, however, that the reported high cloud was actually the leading edge of the approaching smoke pall. "Altostratus overcast" and scattered to broken stratocumulus clouds were noted during the day, and smoke was first officially reported at 1655 EST as "indefinite at 14,000 feet, base estimated at 12,000 feet." As a result of the

*For a more detailed description of the synoptic background accompanying the smoke pall, see a paper by C. D. Smith, Jr., of the Weather Bureau, scheduled for the September, 1950, issue of the *Monthly Weather Review*.

smoke and lower clouds, insolation for the 24th fell to 290 ly. On the 25th and 26th, when no daytime clouds were reported (except for a few cumuli near noon on the 25th), the insolation was 220 ly/day, or 46 per cent of normal for clear days. In other words, more than half of the expected solar radiation failed to reach the ground, and all of this, apart from a small amount absorbed by the smoke particles and the atmosphere, was reflected back to space.

On the 27th, smoke aloft (base 9,000 feet, top 15,000 feet) was still reported, together with surface smoke in the morning, and scattered cumulus in the afternoon. On the 28th, insolation dropped to 110 ly as a result of ground fog, surface smoke, and broken to overcast stratocumulus clouds. Through breaks in the clouds the upper smoke was still observed, base estimated at 9,000 feet. On the 29th, although there was a good deal of lower cloudiness, the smoke aloft was still visible and estimated at 12,000 feet at the 0700 and 1000 EST observations, and at 8,500 feet at 1300 EST. Smoke aloft on the 29th was last reported at 1529 EST; thereafter it may have still been present but invisible because of lower overcast at 3,000 feet. On September 30th, the overcast stratus deck broke shortly after noon, permitting the observer by 1600 EST to ascertain that the smoke aloft had vanished. Insolation remained fairly low on the 29th and 30th, but increased sharply to near 400 ly as October began.

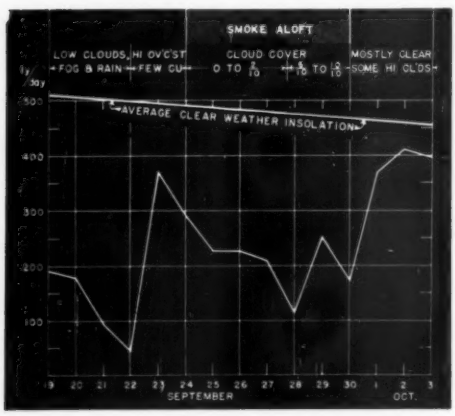


Fig. 5. Average clear weather insolation, observed insolation, and sky obscuration at Washington, D. C., September 19-October 3, 1950. Chart by U. S. Weather Bureau.

The decrease in insolation caused by the smoke resulted in a large decrease of the observed maximum temperatures from those expected. The forecast maximum Fahrenheit temperatures for Washington, D. C., for each day of the period September 24-27 were 64°, 64°, 70°, and 70°, and the observed maximum temperatures were 54°, 59°, 63°, and 66°, respectively. While the large error of 10 degrees on the 24th may have been due partially to difficulty in estimating the effect of cold air advection following the cold front passage late on the 23rd, the remaining forecasts were made during stagnant anticyclonic weather when advection was no longer of importance. The critical factor was the amount of insolation expected during the day, and it is believed that the unexpected persistence of the smoke pall interfered with the normal functioning of the forecasters' experience.

The decrease of the visible portion of the solar spectrum was larger than of the remaining (mostly long-wave) portion. This was noticed at Washington, D. C., by means of radiation equipment, which recorded both the illumination (visible component) and total radiation. A comparison of the records showed a sharp drop in the number of foot-candles (illumination) per ly/minute (total radiation) from 6,500-7,500 prior to September 23rd to 5,500 on the 24th. This drop was already present by 1500 GMT on the 24th; the record on the 23rd was quite variable because of the scattered clouds, and the smoke could not be detected by this means on that day, even if it had been present. The daily average values remained low through September 27th, but on the 28th the average recovered almost to the values noted prior to the 23rd. At Buffalo, because of the presence of both the smoke and clouds, the illumination from 1400 to 1600 EST on the 24th was comparable to pre-dawn or twilight. At Sault Ste. Marie, also with clouds and smoke on the 24th, the insolation dropped to the unusually low value of 4 ly, less than one per cent of the normal clear weather value.

Optical Effects

The greater reduction of the visible radiation compared to the longer wave infrared radiation mentioned in the previous para-

On the night of the total eclipse of the moon, here shown in its partial phases, other cities northeast of Washington reported the moon to be: "purple at times, otherwise of normal color" — Philadelphia; "a bright white, sometimes dim, with an occasional purple cast" — Baltimore; "when visible, the moon had a violet cast" — Newark, New Jersey; "pronounced bluish tinge during the entire period" — Concord, New Hampshire; "unusual grayish cast" — Bridgeport, Connecticut; "pale with a faint bluish tinge" — Boston. Indiana University students at Bloomington, Indiana, took these pictures with a 12-inch telescope, yellow-sensitive film and filter, the left-hand picture 19 minutes before totality. Indiana University photograph.

graph is a good indication of the selective character of the depleted radiation. It is well known from Rayleigh's law that the scattering coefficient for air molecules is inversely proportional to the fourth power of the wave length. Thus, for the visible radiation coming from the sun, violet and blue are scattered strongest, and this accounts for the blue color of the sky. If small foreign particles about the size of the wave length of light (0.5 micron) are also present, they too will have a selective scattering effect on the solar radiation. However, the scattering coefficient for this case will no longer follow such a simple law as the inverse fourth power of the wave length, but rather a complicated function of the ratio of the particle diameter to the wave length of the radiation. Many peaks and valleys are present in the curve computed for small spherical non-absorbing particles having the refractive index of water.[1]

Probably the most striking phenomenon accompanying the smoke was the colored appearance of the sun and, to a lesser extent, of the moon. In Washington the lavender color of the sun was visible to the naked eye on September 25th, 26th, and 27th, particularly before 0830 EST. After that time, the intensity of the sun seemed too bright for the lavender color to be distinguished by the naked eye, but the color was still visible when the sun was viewed through a neutral (gray) celluloid filter. A colored sun was reported in many places in the eastern United States, with colors described as dull red, copper, orange, greenish yellow, pink, silver, purple, blue, violet, and lavender. The last four colors were in the majority, however. The sun was also reported as blue in Scotland, Denmark, and Belgium, on the 26th and 27th of September. A color photograph made at the U. S. Naval Observatory, Washington, D. C., on the morning of the 26th showed the bluish color of the sun.

If the lavender color as observed at Washington can be considered as caused by the depletion of green and yellow from the sunlight, then some speculations are possible as to the size of the scattering particles, under the assumption that they can be considered as small spheres having the refractive index of water. From calculations made by Houghton and Chalker[1], particles of radii 0.5, 1.3, 2.1, 2.9, and 3.6 microns could, by scattering, de-

plete the green portion of the solar spectrum more than the blue and red. Accepting this explanation, it is difficult to explain why the smoke particles should have grouped themselves about one or more of these preferred sizes.

At least, the result that selective scattering requires micron-sized particles is in harmony with the fact that the particles remained airborne for great distances, showing very little fall-out velocity. For example, from Stokes' law, spherical particles of the density of water, having a diameter of one micron, should fall only five inches per hour with respect to the surrounding air.

It has been suggested by Elvey[2] that the apparent blue color of the sun visible to the naked eye in the Midwest during the dust storm of May 10, 1934, was fictitious, and was a result of contrast. Photometric measurements of the sun, using blue and yellow filters, showed a slight tendency for the actual color of the sun to be bluer as seen through the dust cloud, but the difference was thought to be too small to be significant; the appearance of the blue sun was then believed to be "psychological," or dependent on the change of contrast between sun and sky. Elvey states, "One ordinarily sees the sun projected against a blue sky, and of course the sun is yellower than the sky. The dust cloud had a brownish color, and consequently the sun by contrast appeared bluer than normal."

My colleague, S. Fritz, has advanced the following arguments against this interpretation in regard to the Canadian smoke:

1. During the smoky days many weather observers mistook the smoke for middle or high clouds, apparently because the observed color of the sky was very similar to that of clouds (gray or white). On genuinely cloudy or foggy days the sun, when visible, does *not* appear to be colored blue or purple. It usually seems to be silvery white.

2. During the early mornings of the smoky days, the sun appeared blue or purple, but as the solar altitude increased the sun became quite bright and to the naked eye the coloring disappeared. But if several thicknesses of white gauze were held before the eye to cut down the brightness of the sunlight, the purple color was clearly seen. Instead of the gauze, a grayish celluloid filter was held before the eyes. This also cut down the sunlight and made the purple color quite evident. Since to the eye the gray filter apparently changed the color of the sky background and since the sun's blue-purple color did not seem to change despite the possible change in background color, this may indicate that the sun's color was not a psychological effect.

3. Lastly, when the filter was used to view the sun through thin clouds on a day when no Canadian smoke was present, no purple or blue color (or any unusual color) could be detected, even though the sky "looked" rather similar in color to the Canadian smoky sky.

A puzzling feature of the smoke pall was the good visibility of the moon at Washington on the night of September 25th, when a total eclipse of the moon occurred. Observations of this phenomenon appeared to be unaffected by the smoke present during that day and the next day to such an extent that insolation was decreased by 50 per cent. According to the U. S. Naval Observatory in Washington, the moon may have been somewhat fainter than on a "very good night," but the stars were more clearly visible than they had been at any time during the preceding or following week. Not until the night of October 1st were the stars clearly visible again. The astronomers stress the fact that the faint red moon observed during totality would not have been visible if the smoke had been as dense as that on the same day or the following day.

The brightness and lack of color of the moon in Washington on the night of the 25th as compared to the purplish color observed at cities to the northeast indicates that a temporary clearing of the smoke occurred in Washington and vicinity on that night. A trajectory analysis will be made to see if agreement can be found between the optical and aerological observations. A letter by Th. Hesselberg and E. Frogner of the Norwegian Meteorological Institute described the smoke observations in Norway: "We point out that in connection with the coloured sun obviously there have been two phases which are worth mentioning. One phase with a more distinct colour and a more faint light ('pretty' phase) and a *later* phase with a more pale colour and a stronger lustre ('unpleasant' phase)." Both the "pretty" and "unpleasant" phases of the sun were quite apparent in the eastern U. S., and it is remarkable to note that the smoke cloud retained sufficient density in its passage across the Atlantic Ocean to bring about the same optical effects in Europe.

Historical Comparisons

There have been many "dark days" in the past when forest fire smoke or volcanic ash obscured the sun over large areas of the earth's surface. Plummer[3] gives many periods

(Continued on page 142)

Amateur Weathermen of America

Amateur Weathermen of America comprises an association of all followers of the ways of the weather. Its purpose is to enlarge our understanding of weather and climate and to apply this information for the greater enjoyment of life. The Amateur Weathermen is an agency for the exchange of information, both technical and popular, among all interested individuals and groups. It is especially concerned with all projects that will enlarge the scientific outlook of the youth of America. All who enjoy studying any aspect of weather phenomena are eligible for membership and participation in its activities. Write to David M. Ludlum, Director, AWA, Franklin Institute, Philadelphia 3, Pa.

WEATHERWATCH NEEDS LOCAL WEATHER NEWS

Reports of local weather events that have national significance are needed by our publication, *Weatherwatch*, the monthly chronicle of the nation's weather that is sent as a privilege of membership to all members of the Amateur Weathermen of America. This publication carries special maps and charts of each month's temperature and precipitation over the United States.

All observers in the AWA, the American Meteorological Society, and the U. S. Weather Bureau, are requested to make note of weather happenings, and if they are of an unusual nature to send in a postcard report to the editor of *Weatherwatch*, Don C. Cameron.

The publishing of this monthly summary has been a labor of love by Mr. Cameron. He spends many evenings and weekends perusing maps, weather reports, and newspapers, to cull all the information that he condenses into *Weatherwatch*. Of late, this task has been made more difficult by restrictions on the availability of newspapers in the Library of Congress.

It should be emphasized that only reports of national interest need be sent in. Items clipped from newspapers are of special value, as they fill in background material that otherwise would not be immediately available to the editor. All reports should be prepared promptly and mailed to arrive in Washington not later than the last day of the month, in order to be included in the current issue.

Send all reports, preferably on postcards, to: The Editor, Weatherwatch, Box 2227, Washington 13, D. C.

Readers of WEATHERWISE who are not members of the AWA may subscribe to *Weatherwatch* for $1.25 for 12 monthly issues. A free sample issue will be sent upon request.

UPPER MIDWEST WEATHERWATCH

Many WEATHERWISE readers in Wisconsin, Minnesota, and Upper Michigan, will probably be interested to know that their section now has a monthly weatherwatch to report all weather happenings of sectional significance. This publication was started in July, and is a two-page mimeographed sheet. The editor of *Upper Midwest Weatherwatch* is Bruce F. Watson, 517 Germania St., Eau Claire, Wisconsin, an AWA member. All readers who wish to subscribe should write directly to the editor.

WEATHERWISE welcomes this new weather publication, wishes it success, and hopes that other sections will have their own publications soon to give complete coverage of all phases of the nation's weather.

BACK ISSUES AVAILABLE

As WEATHERWISE concludes its third year, requests are being constantly received concerning the availability of back issues. Special reprinting of certain once-exhausted numbers enables us now to supply all needs, and new AWA members are urged to take this opportunity to complete their files, beginning with the first issue in February, 1948. All issues are available in Vol. 1, 1948; Vol. 2, 1949; and Vol. 3, 1950. The price is two dollars per volume of six issues, 35 cents per single copy, postpaid.

U. N. CONTROL?

Responsibilities for legislation and control of artificial precipitation projects should be vested in an international body, Dr. Vincent Schaefer declared recently. Dr. Schaefer, a pioneer in the scientific study of rainmaking, suggested that the United Nations Educational, Scientific, and Cultural Organization (UNESCO) be authorized by international agreement to supervise all cloud-seeding projects.

THE FLORIDA HURRICANE OF OCTOBER 17-18, 1950

A LATE SEASON hurricane, remarkable for its small size and destructive power, moved lengthwise up the Florida peninsula on October 17-18, climaxing the very active hurricane season of 1950. It was the most destructive blow to hit the resort city since the Great Miami Hurricane of 1926, a storm of quite different meteorological characteristics.

The tropical cyclone was first detected on the 15th, in the western Caribbean southwest of Jamaica, a favorite breeding place for October storms. It crossed the coast of central Cuba on the night of the 16-17th, with destructive winds of hurricane force and barometer readings below 29.25 inches. Reforming off the north coast of Cuba, the storm regained full strength and took a peculiar curve to the west-northwest. A close watch was maintained by radar and reconnaissance flights as the center zigzagged toward the mainland (see page 122). The hurricane alert was changed to hurricane warning for the lower Florida coast early on the morning of the 17th.

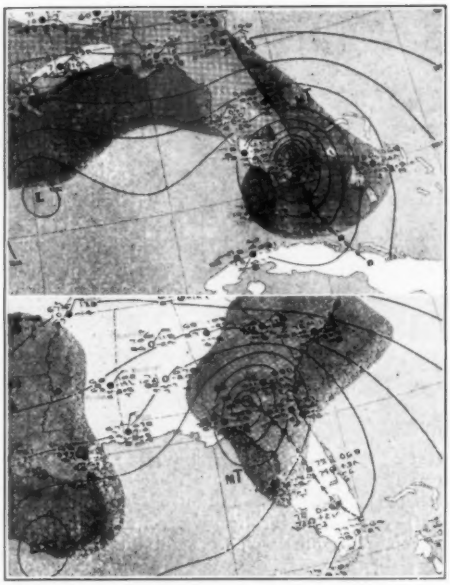
The center moved onshore just south of Miami Beach, and the eye of the storm passed directly over Miami around midnight, with the lull reported as lasting from 25 to 30 minutes. The center was estimated to be six miles in diameter, and the forward speed about 12 miles per hour. It continued northward about 40 miles inland from the east coast, and gradually picked up speed, moving at about 17 miles per hour when it crossed into Georgia.

The city office of the Weather Bureau in downtown Miami was near the eastern rim of the vortex, and experienced the higher wind speeds associated with the dangerous eastern sector of a hurricane. A sustained five-minute speed of 97 miles per hour from the northeast was registered from 11:40 to 11:45 p.m., but the highest one-minute sustained speed was 122 miles per hour from the south at 12:30 a.m., after the center had passed. Observers on duty noticed gust indications up to 150 miles per hour. The barometer dropped to 28.25 inches (956.7 millibars), with a very sharp apex at midnight.

The airport office, six miles to the west, was on the western rim of the center, and experienced a lull between 12:05 and 12:25 a.m., with minimum wind speeds of 18 miles per hour, but no calm. Winds before the lull were clocked at 80 miles per hour sustained speed from the north-northeast, with a gust of 125 miles per hour recorded at 11:55 p.m. On the same airfield, the Pan-American Airways wind equipment showed a gust of 116 miles per hour, at 11:58 p.m. from the north-northeast. Winds following the lull were much lower than preceding. The barograph at the airport dipped to 28.34 inches at midnight.

Damage from the storm in Greater Miami

Property damage from the storm was very great. The fury of the winds toppled these freight cars from their trucks in the Seaboard Railroad yards at the 20th St. airport. Miami *Herald* photograph by Robert Verlin.



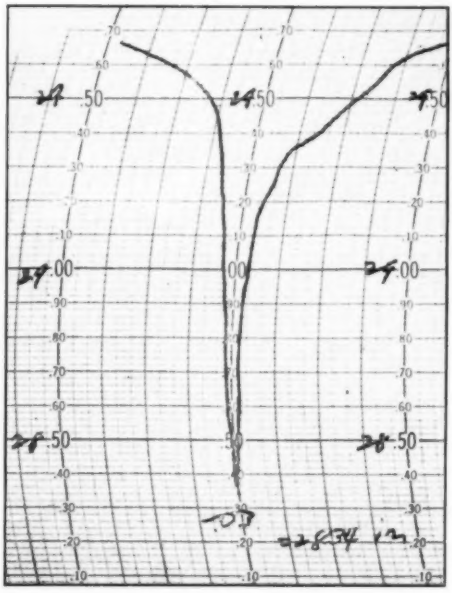
The 1:30 a.m. EST weather maps for October 18th (top) and 19th show how the storm center moved rapidly up the Florida peninsula.

was very heavy, but confined to a relatively small area. Grady Norton, official-in-charge of the Miami Weather Bureau, made an inspection trip through Dade and Broward counties. He found "that the path of extensive damage was about 7 to 10 miles in width and extended from Miami and Miami Beach north-northwestward through the suburban town of Opalocka, Davie, West Hollywood, and West Fort Lauderdale. So sharp was the line of demarcation marking the area of extensive damage from the minor damage that you passed from one to the other within a quarter of a mile. It was almost like a large tornado. The calm center was about six miles in diameter. In the heavy damage zone, there was extensive structural damage, much loss of glass and hardly a roof in the area escaped being badly damaged or stripped entirely."

The hurricane continued northward up the peninsula, remaining about 40 miles inland from the east coast, a course that took it over the eastern shore of Lake Okeechobee and near the populous center of Orlando. Winds of hurricane force were felt all the way to Jacksonville, and very heavy rainfall extended over the South Atlantic states (Jacksonville storm total, 11.73 inches). Damage to citrus and truck crops along the eastern perimeter of the storm was very heavy, with other regions reporting only slight losses.

Early reports indicate that four persons lost their lives as a result of the storm. Property damage mounted to $25,000,000, with 128 homes destroyed and 13,464 residences damaged. Six radio stations in the Miami area had 11 large transmitting towers toppled at the height of the storm. A large hangar at the Orlando airport was completely wrecked by the wind.

While this storm was still raging, another tropical disturbance appeared in the Gulf of Mexico and headed for the central west coast resorts. It did not live up to expectations, however, as dry air fed into the center, and it crossed the coastline near Cedar Key with squalls less than 40 miles per hour. It has been noted that these two storms were apparently dynamically related, acting as a doublet and revolving in a counterclockwise manner about a common center, which itself moved northward.



A reconstructed copy of the original barograph trace as the hurricane passed over Miami, the low point being reached at midnight October 17-18. USWB chart.

FORECASTING THE WEATHER

The Relationship of Temperature and Precipitation over the United States to the Circulation Aloft

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STUDIES OF WINTER PRECIPITATION

THE TWO preceding articles in this series have discussed elementary precipitation processes and their relation to the observed upper-level circulation patterns. Certain parameters, selected on the basis of synoptic experience or theoretical considerations, were correlated with the concomitant precipitation for monthly and 5-day periods. This concluding article will discuss the use of composite charts in the establishment of ideal "wet" and "dry" patterns and in the choice of parameters for graphical correlation. This procedure is applied to the 5-day mean 700-mb maps, and thus far only the winter season has been studied.

The use of composite maps for temperature forecasting was discussed by Martin earlier in this series, and typical "cold" and "warm" maps for various stations were presented. We are here, however, concerned with establishing typical "wet" and "dry" maps. This was done by averaging separately the 700-mb contour patterns associated with the 10 heaviest and 10 lightest precipitation cases (from three winters of data) at each of several selected stations. The patterns of 700-mb height and its departure from normal thus obtained should typify the circulation that accompanies each extreme. Of course, this procedure has maximum usefulness if there is but one basic circulation pattern responsible for each extreme.

The composite "wet" map for Norfolk, Virginia, Fig. 1, shows that the winter 700-mb contour patterns (solid curved lines) which are associated with the greatest precipitation at Norfolk have, on the average, a trough from southern Texas tilting strongly northeastward to the eastern Great Lakes. The height departures from normal (indicated by dashed lines) show that heavy precipitation often occurs with southwesterly departure from normal flow aloft over the southeastern portion of the country. It is rather pertinent to note that the strongest departure from normal gradient is located southwest of the station. This anomalous circulation is undoubtedly indicative of lower-level moisture transport from the Gulf of Mexico and is, in part, responsible for heavy precipitation at the station. Norfolk is well east of the trough and close to the inflection point, in good agreement with Klein's schematic precipitation model (**Weatherwise**, August, 1950). It shou.d not be inferred that heavy precipitation can be produced only in this way, but rather, that heavy is commonly produced at Norfolk by troughs of this general nature and with roughly the same location with respect to the station.

The composite "dry" map for Norfolk, Fig. 2, presents a pattern of small amplitude systems with a less well-defined ridge to the west of Norfolk than one might expect. A study of the individual cases reveals the reason for this. The feature which commonly accompanies dry conditions at Norfolk is indeed a ridge to the west, with west-northwesterly to northwesterly winds to and over the station. However, the ridge

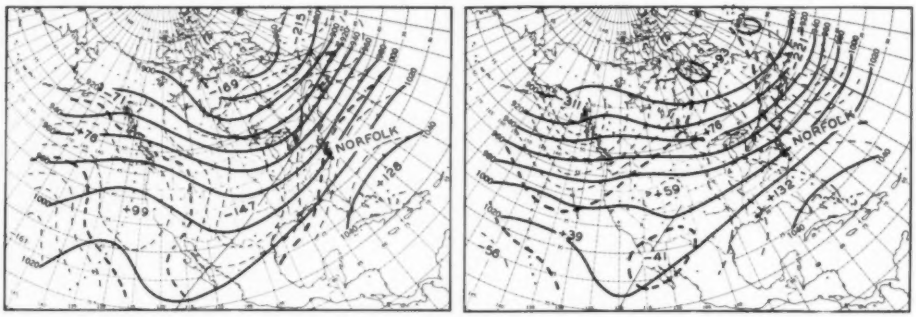
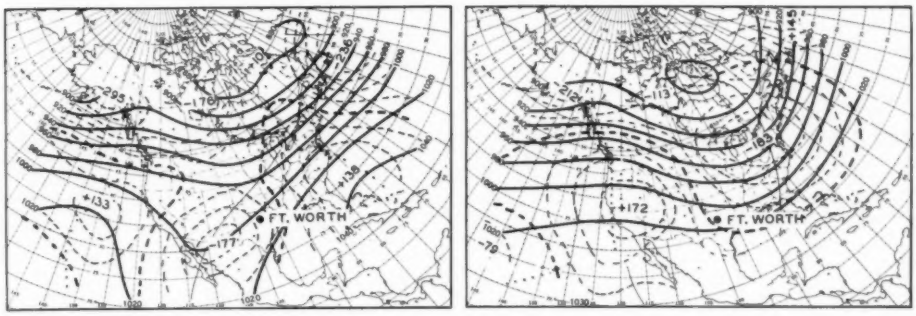


Fig. 1 (left). The composite "wet" map for Norfolk, Virginia (winter, 5-day mean, 500 mb). Fig. 2 (right). The composite "dry" map for Norfolk, Virginia. In Figs. 1 to 6 the contours at 200-foot intervals are shown by solid lines, 700-mb height departures from normal at 50-foot intervals by dashed lines, with zero isopleth heavier. Contours are labeled in tens of feet and departure from normal centers in feet. Minimum latitude trough locations are indicated by light solid lines and the maximum latitude ridge locations by crosses. USWB charts.



Figs. 3 (left) and 4 (right). Composite "wet" and "dry" maps, respectively, for Ft. Worth, Texas. See Figs. 1 and 2 for explanation of symbols.

itself may be located, particularly at the higher latitudes, from just west of Norfolk to quite far to the west, provided that a dry, northwesterly flow prevails. As a consequence of this variation in ridge location, the composite pattern is poorly defined at higher latitudes and lacks the strongly marked features of Fig. 1. The height departures from normal do, however, delineate the most important single feature common to each of the individual patterns, namely, the northerly to northwesterly gradient flow relative to normal over the eastern section of the country.

Another feature of the dry patterns brought into focus by the departures from normal is the fast, westerly flow over the eastern Pacific and western United States. This high-index type of pattern has long been recognized as a producer of dry weather over the eastern two thirds of the United States. Under such a regime little of the moisture from the Pacific survives the long trajectory across the continent, and the weak southwestern United States trough remains undeveloped due to lack of cold air, while Norfolk enjoys a dry period.

One of the more interesting characteristics of the height anomaly patterns is the fact that they do not show a reversal from the light to the heavy patterns, similar to that noted so frequently in the contrasting temperature patterns. Thus the center of negative anomaly on the wet map does not become the center of the positive anomaly on the dry map. This appears reasonable when one considers the moisture source regions for Norfolk. It is evident that, while southwesterly winds aloft are conducive to precipitation, they need only turn to the west-northwest to discourage it. Such a change does not result in a complete reversal of the height anomaly patterns.

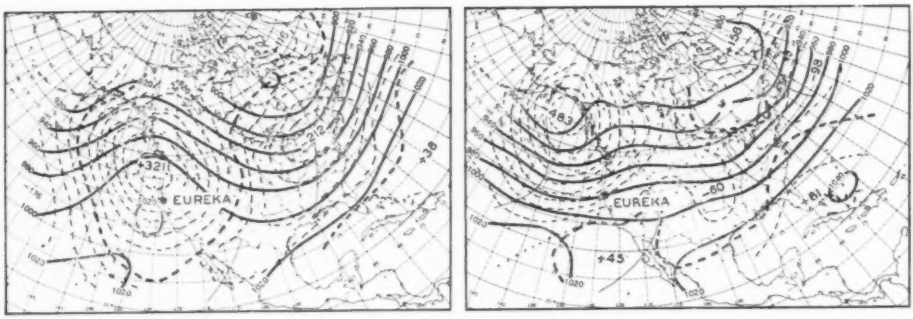
Figure 3 is the composite "wet" or heavy precipitation map for Ft. Worth, Texas. The contour pattern reveals that many of the features which here accompany heavy are similar to those at Norfolk. These include the trough to the west tilting rather strongly northeastward accompanied by a fairly strong southwesterly flow extending from lower latitudes to the station. Both the trough and the negative height anomaly center are much closer to the station than was the case at Norfolk, and both have moved a relatively short distance compared to the change in station location. This is due in part to the fact that the Gulf of Mexico is a common moisture source for both stations.

Since the western limits of the Gulf are sharply defined, the trough cannot retreat much farther west and still draw moisture from this source region, unless it is a large-amplitude system with the southerly flow extending east of the continental divide. Moreover, a flat trough farther west would be located west of the Rocky Mountains. In this location it would not ordinarily be effective in spreading precipitation over the eastern slopes, due to the rain shadow or downslope effect which tends to warm and "dry" the air moving from a westerly direction. (The Appalachian Mountains are too low to produce a similar effect at Norfolk except to a small degree.) Consequently, the most critical parameter of the height anomaly pattern at Ft. Worth is the intense southerly departure from normal gradient flow at 30° north between 80° west and 105° west. The closed negative anomaly center which accompanies this flow results in a weakening of the contour gradient aloft over Colorado and New Mexico, with much weaker westerly winds and a consequent reduction of the foehn drying.

The composite "dry" or light map for Ft. Worth, shown in Fig. 4, is more nearly a reversal of the "wet" than was the case at Norfolk. The ridge to the west of the station producing the west-northwesterly to northwesterly flow is quite analogous to that found on the composite

CORRECTION

An error in proofreading occurred on the first line of the last paragraph, first column, page 116 of the October issue. This line should read: "The graphical approach described has **not** led to" instead of as printed.



Figs. 5 (left) and 6 (right). Composite "dry" and "wet" maps, respectively, for Eureka, California. See Figs. 1 and 2 for explanation of symbols.

"dry" pattern for Norfolk. However, this ridge extends quite strongly and uniformly to higher latitudes over an area which climatologically favors anticyclonic activity.

A study of other stations in the southern and eastern United States gives the same general results as those obtained for Norfolk and Ft. Worth. The moisture, principally from the Gulf of Mexico, is indicated by stronger than normal southwesterly flow anomaly from the region of the Gulf to the station. The two basic anomaly centers are usually located to the southwest and southeast of the station for the "wet" maps and to the northwest and northeast of the station for the "dry" maps. Inspection of the composite "wet" map shows that the farther west the station is situated, the closer the optimum trough location approaches the station and the more important becomes the presence of the closed negative anomaly center to the southwest or south-southwest. This center produces easterly departure from normal gradient flow close to the northwest or north of the station and mitigates the foehn drying.

In the northern plains region the composite height anomaly charts for the "dry" maps are similar to those already mentioned. However, the "wet" maps are different in that the southerly to southwesterly departure from normal gradient flow seldom extends as far as the station. The latter is usually located within the below normal height area and in the region of easterly to northeasterly flow relative to normal. These patterns are indicative of individual storms passing to the south of the station, with precipitation spreading far northward due to overrunning. In addition, precipitation is favored by upslope motion on the eastern slopes of the Rockies.

It is not until we consider the Pacific Coast stations that we find any considerable change of pattern. This more restricted area enjoys a somewhat simpler regime which is worthy of note. The composite charts for Eureka, California, are fairly typical. Fig. 5 shows that dry conditions are accompanied by above normal heights at the station, a strong ridge immediately off the coast, and northeasterly flow relative to normal over the station. The "wet" map, Fig. 6, is almost the reverse, particularly in the critical West Coast area. Nevertheless, the trough-ridge structure shown by the contours is poorly defined. This is apparently due to the fact that the principal cause of heavy precipitation at Eureka is a strong westerly to southwesterly flow of moist Pacific air which is effective regardless of the exact trough and ridge locations. The heights tend to be below normal, but this is not a necessary condition for heavy. The precipitation may be caused by a combination of orographic, frontal, and cyclonic processes acting individually or in concert. Both Spokane and Los Angeles show similar characteristics, although the orographic effect at Los Angeles seems less pronounced.

Just as in the temperature studies, these composite maps have been used as a guide in the selection of some of the parameters to be graphically related to the precipitation. The graphs have not been completed for all of the stations and their effectiveness has not yet been tested. Typical of the stations in the eastern United States is the graph for Evansville, Indiana, shown in Fig. 7. The parameters chosen are the departure from normal of the contour gradient between the approximate locations of the composite anomaly centers (in this case 50° north, 110° west, and 40° north, 70° west), and the longitude of the trough at 35° north. The graph indicates that almost all of the heavy cases occur with the trough (at 35° north) west of the station, and with the flow between the chosen points stronger than normal from the south-southwest (lower left quadrant). Light occurs not only with the trough to the east, but also with the trough to the west if the flow between the two critical points is strong and northerly. This suggests that in the latter situation the cold, dry air is carried through the trough and the overrunning occurs well to the south of the station.

This graph is not a satisfactory answer to

all forecasting needs, reflecting as it does the fact that the presence or absence of precipitation is determined by more than two basic flow patterns. For example, there are fairly frequent occasions when heavy is indicated by the graph but the amounts observed fall in the moderate, or sometimes the light category. These exceptions are often accompanied by a flat pattern over the western United States with the westerlies much stronger than normal. As a consequence, Gulf moisture is unable to penetrate as far north as Evansville, and the Pacific air masses which dominate the country (dried out in being lifted over the Rockies) cannot lead to much precipitation east of the divide. Qualitative allowances may be made for this effect in using the graph.

There are, to be sure, other effects which will influence the precipitation pattern with a given circulation pattern. These include: patterns which are moving or changing rapidly, abnormal distribution of moisture and thermal fields at the beginning of the period, and the marked flowing together of cold and warm air streams (confluence). These factors must, for the present at least, be evaluated qualitatively by the forecaster and used in conjunction with the graphical indications.

At Eureka the factors producing precipitation appear to be relatively simple, so that their graphical representation, shown in Fig. 8, is comparatively free of the defects noted above. In this example, we are assured that a southwesterly flow contains adequate moisture and that the timing of disturbances in the flow may affect but will not control the precipitation, which is in part orographic. The first parameter is the departure from normal of the contour gradient between 50° north, 130° west, and 30° north, 110° west, and represents the strength of the southwesterly flow relative to normal over Eureka. The second parameter is the height anomaly intermediate between these two points at 40° north, 120° west. These parameters were selected largely on the basis of the composite patterns. It will be noted that they are similar to those selected for the monthly study reported in the preceding article. The analysis of the precipitation for the classes light, moderate, and heavy was quite simple and satisfactory. It is even possible to estimate the actual amounts, as suggested by the dashed lines drawn on the figure. It appears pertinent that out of 30 cases of light rainfall, 18 were no-rain cases, and 13 of these were segregated to the right of the zero line on the graph.

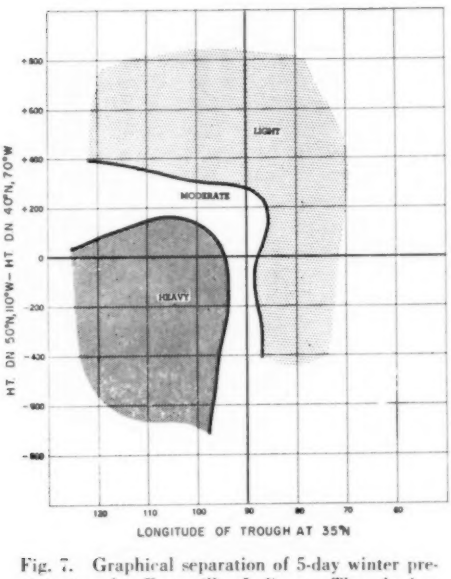


Fig. 7. Graphical separation of 5-day winter precipitation for Evansville, Indiana. The abscissa indicates the longitude of the trough at 35° north. The ordinate is the departure from normal of the height difference (in feet) at 700 mb between 50° north, 110° west, and 40° north, 70° west, with the positive values indicating anomalous gradient flow from the north. The 5-day class limits are: light, 0.00 to 0.09 inch; moderate, 0.10 to 0.54 inch; heavy, over 0.55 inch. USWB chart.

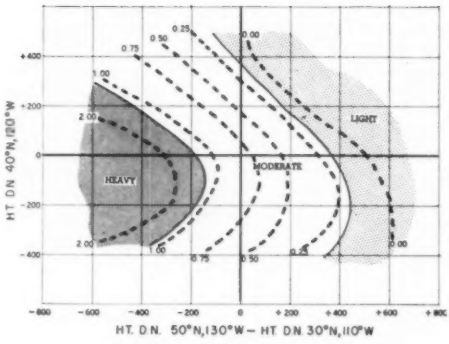


Fig. 8. Graphical separation of 5-day winter precipitation for Eureka, California. The abscissa is the departure from normal of the height difference (in feet) at 700 mb between the points 50° north, 130° west, and 30° north, 110° west, with southwesterly gradient flow increasing from right to left. The ordinate is the 700-mb height departure from normal (in feet) at the point 40° north, 120° west. USWB chart.

These studies of precipitation as related to circulation are far from completion. Nevertheless, it is hoped that these articles have given the reader some idea about the principal aspects of the phenomena and how the longer-range forecasts utilize these concepts in relating the weather to the circulation patterns.

The authors take this opportunity to thank Jerome Namias, Philip F. Clapp, William H. Klein, and Walter G. Leight, of the Extended Forecast Section of the U. S. Weather Bureau, for their helpful suggestions and editing.

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THE GREAT SMOKE PALL

(Continued from page 134)

of dark days in the United States and Canada beginning with 1706, most of them caused presumably by forest fire smoke. No mention is made of unusually colored sun or moon. Smoke from the great Minnesota forest fire of October 13-17, 1918, reached the Atlantic seaboard in the surface air;[4] the sun was reported variously to look like a "red moon" or "took on a greenish-yellow appearance." No mention of a lavender or blue sun caused by that or any other forest fire smoke has been found in the literature. Nor were any colored suns reported during the great Pacific haze of June, 1950 (see WEATHERWISE, August, 1950). However, the explosion of the Krakatoa volcano did cause a blue or green sun and moon to be visible over great areas.[5] At one station violet as well as blue and green suns were observed at different times.

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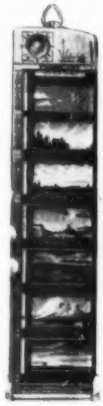

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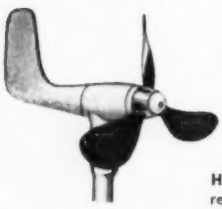

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